# ANNUAL REPORT
to the
# GOVERNMENTS
of
# THE UNITED STATES and CANADA

COLUMBIA RIVER TREATY
PERMANENT ENGINEERING BOARD

Washington, D.C. Ottawa, Ontario

30 SEPTEMBER 1991

93-00597/

# COLUMBIA RIVER TREATY PERMANENT ENGINEERING BOARD

CANADA • UNITED STATES

CANADIAN SECTION
J. D. OULTON, Chairman
J. Allan, Member

UNITED STATES SECTION
H. H. KENNON, Chairman
R. H. Wilkerson, Member

31 December 1991

The Honorable James Baker
The Secretary of State
Washington, DC

The Honourable Jake Epp
Minister of Energy, Mines and Resources
Ottawa, Ontario

Gentlemen:

Reference is made to the Treaty between the United States of America and Canada, relating to co-operative development of the water resources of the Columbia River basin, signed at Washington, DC, on 17 January 1961.

In accordance with the provisions of Article XV paragraph 2(e), there is submitted herewith the twenty-seventh Annual Report, dated 30 September 1991, of the Permanent Engineering Board.

The report sets forth results achieved and benefits produced under the Treaty for the period from 1 October 1990 to 30 September 1991.

Respectfully submitted:

For the United States

Herbert H. Kennon, Chairman

Ronald H. Wilkerson

For Canada

J. D. Oulton, Chairman

J. Allan

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Photographs supplied by the British Columbia Hydro and Power Authority and the U.S. Army Corps of Engineers.

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## ACKNOWLEDGEMENT

This report is dedicated to Mr. Gordon M. MacNabb, Chairman of the Canadian Section of the Permanent Engineering Board from 1964 when the Board was created, until he left the Board in 1991, a period of 27 years.

Mr. MacNabb participated in the development and negotiation of the Columbia River Treaty before becoming a member of the Board. This experience, his remarkable personal abilities, his high professional values and his unrelenting dedication to uphold the Treaty resulted in an outstanding contribution to Canada and the United States in managing the water resources of the basin.

Members of the Board and the Engineering Committee are proud to have had the honour and pleasure of working with Gordon.

## SUMMARY

The twenty-seventh annual Report of the Permanent Engineering Board is submitted to the Governments of the United States and Canada in compliance with Article XV of the Columbia River Treaty of 17 January 1961. The status of projects, progress of Entity studies, operation of Duncan, Arrow, Mica and Libby reservoirs, and the resulting benefits are described.

The Duncan, Arrow, Mica and Libby storage projects were operated throughout the year in accordance with the objectives of the Treaty and the terms of operating plans developed by the Entities. Operations under the 1984 non-Treaty storage agreement between the Entities relating to the use of non-Treaty storage, refill enhancement for Mica and Arrow reservoirs, and initial filling of non-Treaty reservoirs did not conflict with Treaty operations. Treaty reservoirs were operated on a daily basis for flood control purposes during the year (pages 26-32).

Studies pertaining to development of the hydrometeorological network, power operating plans and calculations of downstream power benefits are being continued by the Entities to ensure compliance with the terms of the Treaty.

The Assured Operating Plan and downstream benefit document for 1996-97 was not received. The Board expressed interest to the Entities in being able to review this document at an early date. The corresponding document for 1997-98, due for completion in October 1992, will be the first to contain benefits not covered by the Sales Agreement.

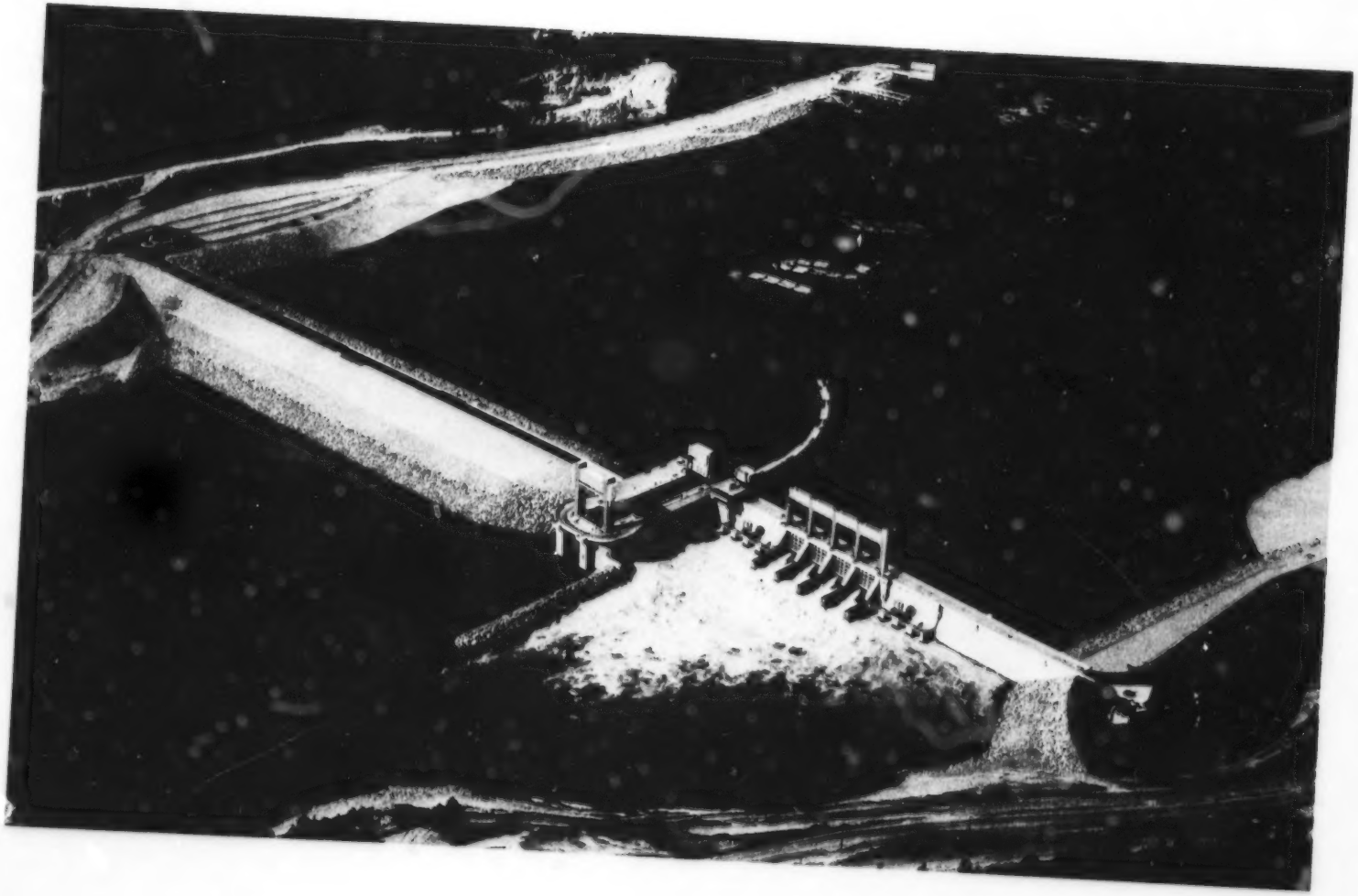
The Entities are continuing to develop plans for return of the Canadian Entitlement commencing in operating year 1997-98. A common understanding has not yet been reached as to how the limitations to the capacity credit portion of the Entitlement should be determined. Entity evaluations are continuing. The Board notes the importance of this matter and looks forward to its timely resolution within the coming year.

The Board concludes that the objectives of the Treaty are being met.

## INTRODUCTION

The Columbia River Treaty, which provides for cooperative development of the water resources of the Columbia River basin, was signed in Washington, D.C. on 17 January 1961 by representatives of the United States and Canada. Article XV of the Treaty established a Permanent Engineering Board and specified that one of its duties would be to "make reports to Canada and the United States of America at least once a year of the results being achieved under the Treaty . . ."

This Annual Report, which covers the period 1 October 1990 through 30 September 1991, describes activities of the Board, progress being achieved by both countries under the terms of the Treaty, operation of the Treaty projects, and the resulting benefits. Summaries of the essential features of the Treaty and of the responsibilities of the Board and of the Entities are included. The report refers to items currently under review by the Entities, provides discussion regarding the operations of the Treaty reservoirs and of the resulting power and flood control benefits, and presents the conclusions of the Board.



HUGH KEENLEYSIDE DAM
Columbia River, British Columbia
Concrete spillway and discharge works with navigation lock and earth dam.

## THE COLUMBIA RIVER TREATY

### General

The Columbia River Treaty was signed in Washington, D.C. on 17 January 1961 and was ratified by the United States Senate in March of that year. In Canada ratification was delayed. Further negotiations between the two countries resulted in formal agreement by an exchange of notes on 22 January 1964 to a Protocol to the Treaty and to an Attachment Relating to Terms of Sale. The Treaty and related documents were approved by the Canadian Parliament in June 1964.

The Canadian Entitlement Purchase Agreement was signed on 13 Aug 1964. Under the terms of this agreement Canada's share of downstream power benefits resulting from the first thirty years of scheduled operation of each of the storage projects was sold to a group of electric utilities in the United States known as the Columbia Storage Power Exchange.

On 16 September 1964 the Treaty and Protocol were formally ratified by an exchange of notes between the two governments. The sum of $253.9 million (U.S. funds) was delivered to the Canadian representatives as payment in advance for the Canadian entitlement to downstream power benefits during the period of the Purchase Agreement. On the same date at a ceremony at the Peace Arch Park on the International Boundary the Treaty and its Protocol were proclaimed by President Johnson, Prime Minister Pearson, and Premier Bennett of British Columbia.

## Features of the Treaty and Related Documents

The essential undertakings of the Treaty are as follows:

(a) Canada will provide 15.5 million acre-feet of usable storage by constructing dams near Mica Creek, the outlet of Arrow Lakes and Duncan Lake, in British Columbia.

(b) The United States will maintain and operate hydroelectric power facilities included in the base system and any new main-stem projects to make the most effective use of improved streamflow resulting from operation of the Canadian storage. Canada will operate the storage in accordance with procedures and operating plans specified in the Treaty.

(c) The United States and Canada will share equally the additional power generated in the United States as a result of river regulation by upstream storage in Canada.

(d) On commencement of the respective storage operations the United States will make payments to Canada totalling $64.4 million (U.S. funds) for flood control provided by Canada.

(e) The United States has the option of constructing a dam on the Kootenai River near Libby, Montana. The Libby reservoir would extend some 42 miles into Canada and Canada would make the necessary Canadian land available for flooding.

(f) Both Canada and the United States have the right to make diversions of water for consumptive uses and, in addition, after September 1984 Canada has the option of making for power purposes specific diversions of the Kootenay River into the headwaters of the Columbia River.

(g) Differences arising under the Treaty which cannot be resolved by the two countries may be referred by either to the International Joint Commission or to arbitration by an appropriate tribunal as specified by the Treaty.

(h) The Treaty shall remain in force for at least 60 years from its date of ratification, 16 September 1964.

The Protocol of January 1964 amplified and clarified certain terms of the Columbia River Treaty. The Attachment Relating to Terms of Sale signed on the same date established agreement that under certain terms Canada would sell in the United States its entitlement to downstream power benefits for a 30-year period. The Canadian Entitlement Purchase Agreement of 13 August 1964 provided that the Treaty storages would be operative for power purposes on the following dates:

| | |
|---|---|
| Duncan storage | 1 April 1968 |
| Arrow storage | 1 April 1969 |
| Mica storage | 1 April 1973 |

## PERMANENT ENGINEERING BOARD

### General

Article XV of the Columbia River Treaty established a Permanent Engineering Board consisting of two members to be appointed by Canada and two members by the United States. Appointments to the Board were to be made within three months of the date of ratification. The duties and responsibilities of the Board were also stipulated in the Treaty and related documents.

### Establishment of the Board

Pursuant to Executive Order No. 11177 dated 16 September 1964 the Secretary of the Army and the Secretary of the Interior on 7 December 1964 appointed two members and two alternate members to form the United States Section of the Permanent Engineering Board. Pursuant to the Department of Energy Organization Act of 4 August 1977 the appointments to the United States Section of the Board are now made by the Secretary of the Army and the Secretary of Energy. The members of the Canadian Section of the Board were appointed by Order in Council P.C. 1964-1671 dated 29 October 1964. Each member was authorized to appoint an alternate member. On 11 December 1964 the two governments announced the composition of the Board.

The names of Board members, alternate members and secretaries are shown in Appendix A. It is noted that on 30 April 1991, Mr. John Allan succeeded Mr. Douglas Horswill as a member for Canada, and that on 19 November 1991, Mr. David Oulton succeeded Mr. Gordon MacNabb as Chairman of the Canadian Section of the Board.

The names of the current members of the Board's Engineering Committee are also shown in Appendix A.

## Duties and Responsibilities

The general duties and responsibilities of the Board to the governments, as set forth in the Treaty and related documents, include:

(a) assembling records of the flows of the Columbia River and the Kootenay River at the Canada-United States of America boundary;

(b) reporting to Canada and the United States of America whenever there is substantial deviation from the hydroelectric and flood control operating plans and if appropriate including in the report recommendations for remedial action and compensatory adjustments;

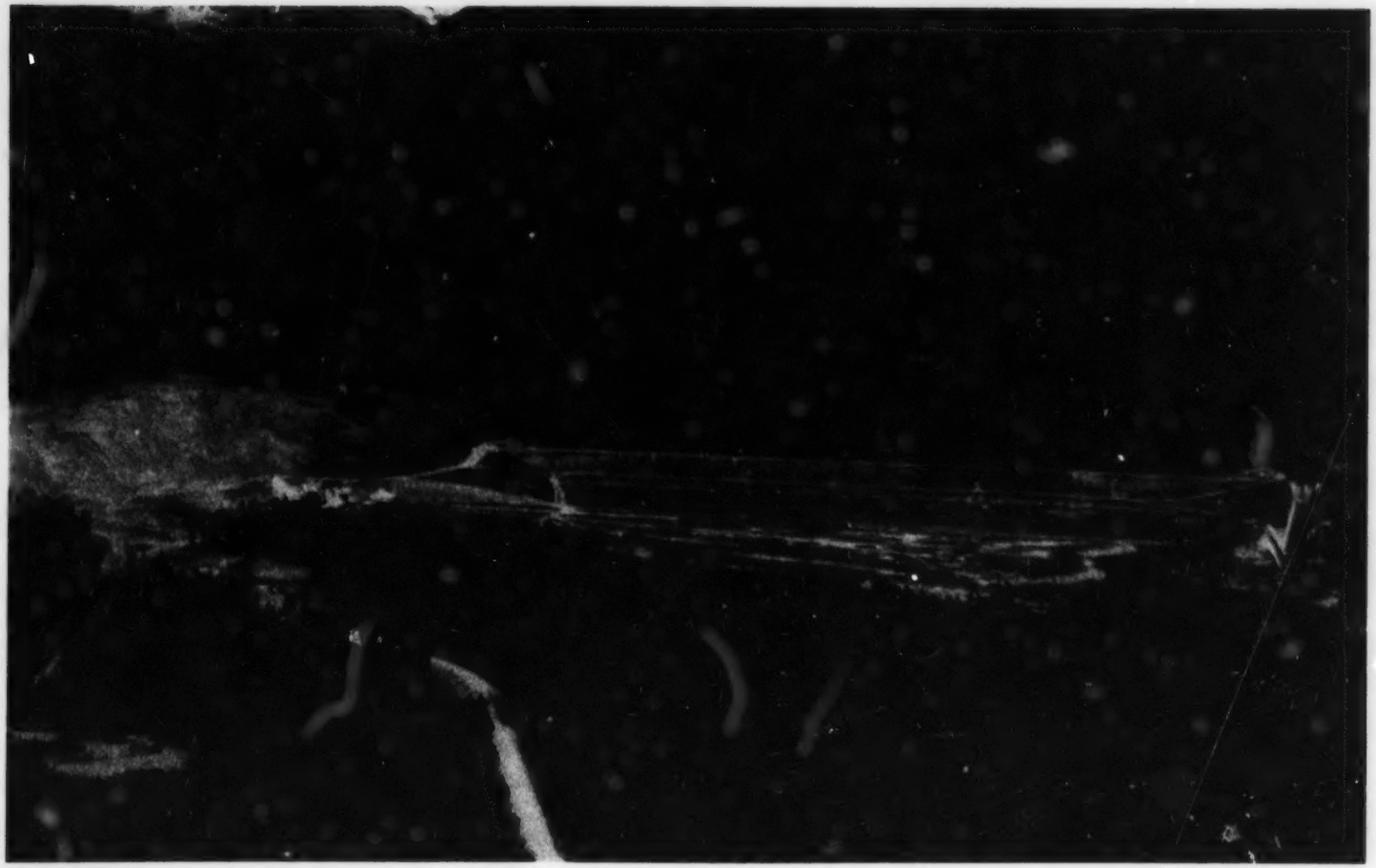
(c) assisting in reconciling differences concerning technical or operational matters that may arise between the entities;

(d) making periodic inspections and requiring reports as necessary from the entities and with a view to ensuring that the objectives of the Treaty are being met;

(e) making reports to Canada and the United States of America at least once a year of the results being achieved under the Treaty and making special reports concerning any matter which it considers should be brought to their attention;

(f) investigating and reporting with respect to any other matter coming within the scope of the Treaty at the request of either Canada or the United States of America;

(g) consulting with the entities in the establishment and operation of a hydro-meteorological system as required by Annex A of the Treaty.



DUNCAN DAM Duncan River, British Columbia
The earth dam with discharge tunnels to the left and spillway to the right.

## ENTITIES

### General

Article XIV(1) of the Treaty provides that Canada and the United States shall each designate one or more entities to formulate and execute the operating arrangements necessary to implement the Treaty. The powers and duties of the entities are specified in the Treaty and its related documents.

### Establishment of the Entities

Executive Order No. 11177, previously referred to, designated the Administrator of the Bonneville Power Administration, Department of the Interior, and the Division Engineer, North Pacific Division, Corps of Engineers, Department of the Army, as the United States Entity with the Administrator to serve as Chairman. Pursuant to the Department of Energy organization Act of 4 August 1977 the Bonneville Power Administration was transferred to the Department of Energy. Order In Council P.C. 1964-1407 dated 4 September 1964 designated the British Columbia Hydro and Power Authority as the Canadian Entity.

The names of the members of the two Entities are shown in Appendix B. It is noted that on 16 August 1991 Mr. Jack Robertson became Acting Chairman of the United States Entity in place of Mr. James Jura, the previous Chairman. On 22 November 1991, Mr. Randall W. Hardy became Chairman of the United States Entity. Major General Ernest J. Harrell succeeded Brigadier General Pat M. Stevens IV as a member of the United States Entity on 2 March 1991.

Mr. W. R. Wyman succeeded Mr. L. I. Bell as Chairman of the Canadian Entity on 1 March 1991.

Powers and Duties of the Entities

In addition to the powers and duties specified elsewhere in the Treaty and related documents, Article XIV(2) of the Treaty requires that the entities be responsible for:

(a) coordination of plans and exchange of information relating to facilities to be used in producing and obtaining the benefits contemplated by the Treaty;

(b) calculation of and arrangements for delivery of hydroelectric power to which Canada is entitled for providing flood control;

(c) calculation of the amounts payable to the United States for standby transmission services;

(d) consultation on requests for variations made pursuant to Articles XII(5) and XIII(6);

(e) the establishment and operation of a hydrometeorological system as required by Annex A;

(f) assisting and cooperating with the Permanent Engineering Board in the discharge of its functions;

(g) periodic calculation of accounts;

(h) preparation of the hydroelectric operating plans and the flood control operating plans for the Canadian storage together with determination of the downstream power benefits to which Canada is entitled;

(i) preparation of proposals to implement Article VIII and carrying out any disposal authorized or exchange provided for therein;

(j) making appropriate arrangements for delivery to Canada of the downstream power benefits to which Canada is entitled including such matters as load factors for delivery, times and points of delivery, and calculation of transmission loss;

(k) preparation and implementation of detailed operating plans that may produce results more advantageous to both countries than those that would arise from operation under the plans referred to in Annexes A and B.

Article XIV(4) of the Treaty provides that the two governments may, be an exchange of notes, empower or charge the entities with any other matter coming within the scope of the Treaty.

## ACTIVITIES OF THE BOARD

### Meetings

The Board met in Victoria, British Columbia on 29 November 1990 to review progress under the Treaty and to discuss preparation of the Board's Annual Report. The Board met with the entities on the same day to discuss entity studies and general progress. The Board also met in Seattle, Washington on 25 April 1991 to review progress under the Treaty and to receive a briefing from the Entities on the status of Entity discussions regarding limitation of capacity credits under the Treaty.

### Reports Received

Throughout the report year the Canadian Entity provided the Board with weekly reports on operation of the Canadian storage reservoirs and with daily flow forecasts during the freshet season for the northern part of the Columbia River basin. The United States Entity provided monthly reports on the operation of the Libby storage reservoir. The Entities made copies of computer printouts of studies for the Assured Operating Plan and Determination of Downstream Power Benefits available for review and provided the following documents and reports to the Board:

— Annual Report of Columbia River Treaty, Canadian and United States Entities 1 October 1989 through 30 September 1990

— Detailed Operating Plan for Columbia River Treaty Storage 1 August 1990 through 31 July 1991, September 1990, plus a copy of the Entities' agreement on this document

— Assured Operating Plan and Determination of Downstream Power Benefits for Operating Year 1994-95, October 1990

— Assured Operating Plan and Determination of Downstream Power Benefits for Operating Year 1995-96, October 1990

— Columbia River Treaty Hydrometeorological Facilities, November 1990

— Assured Operating Plan, Determination of Downstream Power Benefits and Options for Development of the Detailed Operating Plan for Operating Year 1994-95, January 1991, plus a copy of the Entities' agreement on this document

— Assured Operating Plan, Determination of Downstream Power Benefits and Options for Development of the Detailed Operating Plan for Operating Year 1995-96, January 1991, plus a copy of the Entities' agreement on this document

— Agreement executed by the United States of America Department of Energy acting by and through the Bonneville Power Administration and British Columbia Hydro and Power Authority relating to: (1) Use of Columbia River non-Treaty Storage, (2) Mica and Arrow Refill Enhancement, and (3) Initial Filling of non-Treaty Reservoirs, signed 9 July 1990

— Canadian Method for Limitation of the Capacity Credit Resulting from Canadian Storage Provided Under the Columbia River Treaty, dated 19 February 1991

— United States Method for Limitation of the Capacity Credit Resulting from Canadian Storage Provided Under the Columbia River Treaty, dated 15 March 1991

— Columbia River Entity Agreement on Implementation of the Assured Operating Plan for the Operating Year 1993-94, 1 March 1991

The Entities did not sign an agreement on the two Assured Operating Plan and Determination of Downstream Power Benefits documents for Operating Years 1994-95 and 1995-96, dated October 1990. These documents were replaced by the two approved documents dated January 1991 (page 21).

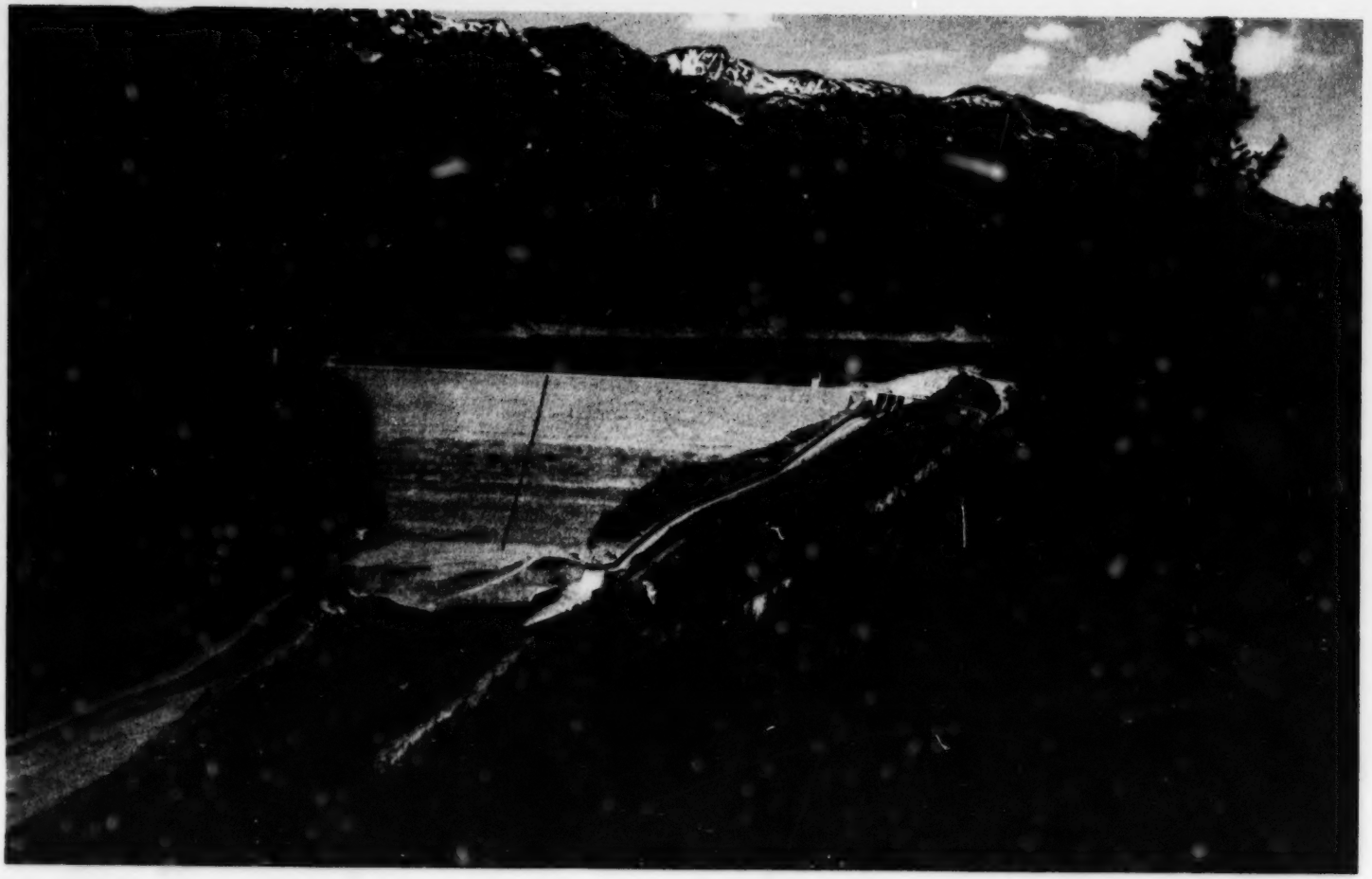
Subsequent to the end of this report year, the Board received the following documents and reports from the Entities:

— Annual Report of the Columbia River Treaty, Canadian and United States Entities 1 October 1990 through 30 September 1991, November 1991

— Detailed Operating Plan for Columbia River Treaty Storage 1 August 1991 through 31 July 1992, November 1991.

Report to Governments

The twenty-sixth Annual Report of the Board was submitted to the two governments on 31 December 1990.



**MICA DAM** Columbia River, British Columbia
The earth dam showing the spillway at the right. The underground powerhouse is at the left.

## PROGRESS

### General

The results achieved under the terms of the Treaty include construction of the Treaty projects, development of the hydrometeorlogical network, annual preparation of power and flood control operating plans, and the annual calculation of downstream power benefits. The three Treaty storage projects in British Columbia, the Duncan, Arrow and Mica projects, produce power and flood control benefits in both Canada and the United States. The Libby storage project provides power and flood control benefits in both Canada and the United States. The Libby storage project provides power and flood control benefits in both countries. In the United States increased flow regulation provided by Treaty projects has facilitated the installation of additional generating capacity at existing plants on the Columbia River. In Canada completion of the Canal Plant on the Kootenay River in 1976, installation of generators at Mica Dam in 1976-77 and the completion of the Revelstoke project in 1984 have caused power benefits to increase substantially. This amounts to some 4,000 megawatts of generation in Canada that may not have been installed without the Treaty. In addition, the installation of generating capacity at Hugh Keenleyside Dam and at the Murphy Creek Site near Trail, British Columbia is planned for the future.

The Treaty provides Canada with an option, which commenced in 1984, of diverting the Kootenay River at Canal Flats into the headwaters of the Columbia River. The British Columbia Hydro and Power Authority has completed engineering feasibility and detailed environmental studies of the potential diversion.

The locations of the above projects are shown on Plate 1 in Appendix D.

## Status of the Treaty Projects

### Duncan Project

Duncan Dam, the smallest Treaty project, was scheduled by the Sales Agreement for operation by 1 April 1968 and was the first of the Treaty projects to be completed. It became fully operational on 31 July 1967, well in advance of Treaty requirements.

The earthfill dam, about 130 feet high, is located on the Duncan River a few miles north of Kootenay Lake. The reservoir behind the dam extends for about 27 miles and provides 1,400,000 acrefeet of usable storage which is all committed under the Treaty. There are no power facilities included in this project.

The project is shown in the picture on page 8 and project data are provided in Table 1 of Appendix D.

### Arrow Project

The Hugh Keenleyside Dam, at the outlet of the Arrow Lakes, was the second Treaty project to be completed. It became operational on 10 October 1968, well ahead of the date of 1 April 1969 scheduled by the Sales Agreement. The project at present has no associated power facilities, however, installation of generators is planned for the future.

The dam consists of two main components: a concrete gravity structure which includes the spillway, low-level outlets and navigation lock and an earthfill section which rises 170 feet above the riverbed. The reservoir, about 145 miles long, includes both the Upper and Lower Arrow Lakes, and provides 7,100,000 acre-feet of Treaty storage.

The project is shown in the picture on page 2 and project data are provided in Table 2 of Appendix D.

## Mica Project

Mica Dam, the largest of the Treaty projects, was scheduled by the Sales Agreement for initial operation on 1 April 1973. The project was declared operational and commenced storing on 29 March 1973.

Mica Dam is located on the Columbia River about 85 miles north of Revelstoke, British Columbia. The earthfill dam rises more than 800 feet above its foundation and creates a reservoir 135 miles long, Kinbasket Lake, with a storage capacity of 20,000,000 acre-feet. The project utilizes 12,000,000 acre-feet of live storage of which 7,000,000 acre-feet are committed under the Treaty.

The underground powerhouse has space for a total of six 434 megawatt units with a total capacity of 2,604 megawatts. The first two generators were placed in service late in 1976 and the last of the initial four units commenced operation in October 1977.

The project is shown in the picture on page 15 and project data are provided in Table 3 of Appendix D.

## Libby Project in the United States

Libby Dam is located on the Kootenai River 17 miles northeast of the town of Libby, Montana. Construction began in the spring of 1966, storage has been fully operational since 17 April 1973, and commercial generation of power began on 24 August 1975, coincident with formal dedication of the project. The concrete gravity dam rises 370 feet above the riverbed and creates Lake Koocanusa which is 90 miles long and extends 42 miles into Canada. Lake Koocanusa has a gross storage of 5,869,000 acre-feet, of which 4,980,000 acre-feet are usable for flood control and power purposes. The Libby powerhouse, completed in 1976, had four units with a total installed capacity of 420 megawatts.

Construction of four additional units was initiated during fiscal year 1978 and the turbines have been installed. However, Congressional restrictions imposed in the 1982 Appropriations Act provide for completion of only one of these units. That unit became available for service late in 1987. The total installed capacity for the five units is 525 megawatts.

The Libby project is shown in the picture on page 23 and project data are provided in Table 4 of Appendix D.

Libby Project in Canada

Canada has fulfilled its obligation to prepare the land required for the 42-mile portion of Lake Koocanusa in Canada. British Columbia Hydro and Power Authority is now responsible for reservoir maintenance, debris clean-up and shoreline activities.

Hydrometeorological Network

One of the responsibilities assigned to the Entities by the Treaty is the establishment and operation, in consultation with the Permanent Engineering Board, of a hydrometeorlogical system to obtain data for detailed programming of flood control and power operation. This system includes snow courses, meteorological stations and streamflow gauges. The Columbia River Treaty Hydrometeorological Committee, formed by the Entities, makes recommendations on further development of the Treaty Hydrometeorological System.

In developing the hydrometeorological network, the Entities, with the concurrence of the Board, adopted a document in 1976 which defines the Columbia River Treaty Hydrometeorological System Network and sets forth a method of classifying facilities into those required as part of the Treaty System and those of value as Supporting Facilities. During the 1976-77 report year, the Entities, with the concurrence of the Board, adopted a plan for exchange of operational hydrometeorological data. That plan is still in force.

In the 1985-86 report year the Entities provided the Board with a report "Revised Hydrometeorological Committee Documents", dated November 1985. The list of hydrometeorological facilities included in this document was updated by the Entities in 1987 and 1989. During this report year a further revision, dated November 1990, of the hydrometeorological facilities which now constitute the network was provided to the Board.

## Power Operating Plans and Annual Calculation of Downstream Benefits

The Treaty and related documents provide that the Entities are to agree annually on operating plans and on the resulting downstream power benefits for the sixth succeeding year of operation. These operating plans, prepared five years in advance, are called Assured Operating Plans. They represent the basic commitment of the Canadian Entity to operate the Canadian Treaty storage and provide the Entities with a basis for system planning. Canada's commitment to operate under an Assured Operating Plan is tied directly to the benefits produced by that plan. At the beginning of each operating year, a Detailed Operating Plan which includes Libby reservoir is prepared on the basis of current resources and loads to obtain results that may be more advantageous to both countries than those which would be obtained by operating in accordance with the Assured Operating Plan.

Near the end of the 1987-88 report year the Entities signed two agreements relating to changes in the principles and procedures used in preparing the assured operating plans and in calculating downstream power benefits. These agreements were based on Entity studies of the impact of several proposed changes to Treaty reservoir operating procedures and to the determination of downstream power benefits. Specific changes resulting from the agreements include the use of updated streamflows in all steps of the calculations, updated estimates of irrigation withdrawals and return flows, a revised definition of power loads and generating resources, the use of updated power system operating technology, and consistent application of operating procedures through all steps of the calculations. The Board agrees with the Entities' view that these studies represent the most thorough and complex examination of the technical aspects of the Columbia River Treaty since the ratification in 1964.

The Board also agrees that the changes provided in the two Entity agreements resolved the concerns which the Board had expressed in annual reports prior to 1988.

Two documents the "Assured Operating Plan, Determination of Downstream Power Benefits and Options for Development of the Detailed Operating Plan for Operating Year 1994-95" and a similar document for operating year 1995-96 were provided to the Board during the report year. These documents follow the same basic approach used in previous years, providing for optimum generation in both countries. These are the third and fourth operating plans based on the 1988 principles and procedures. These plans include firm energy shifting as part of the United States optimum operation. For comparison purposes, the documents include an alternative operating plan that excludes energy shifting. The comparison shows that for each year firm energy shifting creates benefits to each country in the amount of 20.9 megawatts of average annual energy and a decrease in each country's dependable capacity benefit of 2.1 megawatts. The United States Entity will deliver 20.9 megawatts of average annual energy to the Canadian Entity during 1994-95 and again during 1995-96.

It is noted that the first draft Assured Operating Plans for both years 1994-95 and 1995-96 were provided to the Board in October 1990 without having been agreed to by the Entities. In a preliminary review of these documents, the Board expressed concern over the concept of an Alternative Assured Operating Plan. The Board asked the Entities to clearly establish a single Assured Operating Plan for each of the two operating years. The Entities replaced the Assured Operating Plan documents, dated October 1990, with a new set dated January 1991, and provided an Entity agreement on these new documents. The Board notes that the new documents resolved its concerns, and that the technical content of the updated documents does not differ from the draft documents dated October 1990.

The use of half-months in the critical period of the Step III studies used to determine downstream benefits was brought to the attention of the Entities during the previous report year. The Board has reserved judgment on this practice of using half-months pending the Entities' review.

Streamflows used in these Assured Operating Plans were derived from the 1980 level Modified Streamflows with irrigation depletion estimates interpolated between the 1980 and 2030 values. The Entities are updating actual and projected irrigation depletion data.

During the report year the Entities provided the Board with an Entity agreement entitled "Columbia River Entity Agreement on Implementation of the Assured Operating Plan for the Operating Year 1993-94", dated 1 March 1991. This agreement provided for a change in the computation of payment to Canada for additional downstream benefits resulting from the inclusion of firm energy shifting in the Assured Operating Plan for 1993-94, and for an alternative method for implementing the firm energy shift operation in developing the Detailed Operating Plan for 1993-94. The Board accepted this Entity Agreement on the basis that the change in payment computation constituted a correction to the Assured Operating Plan. The Board considered that this change together with the provision for an alternative method for implementing the Detailed Operating Plan, does not alter the Assured Operating Plan, a procedure not provided for by the Treaty.

The Assured Operating Plan and Determination of Downstream Power Benefits document, for operating year 1996-97 was not received. The Board expressed to the Entities its interest in being able to review the document at an early date.

The Board notes that the Assured Operating Plan and Determination of Downstream Power Benefits for Operating Year 1997-98, normally completed by the fall of 1992, will determine a power entitlement from Duncan reservoir not covered by the existing Sales Agreement. The Board has been briefed by the Entities on the status of planning for the return of downstream benefits to Canada, beginning in the 1997-98 operating year.

Early in this report year the Entities provided the Board with the Detailed Operating Plan for Canadian Treaty storage and Libby reservoir for the operating year ending 31 July 1991. The Detailed Operating Plan for the operating year ending 31 July 1992 was forwarded to the Board after the end of the report year and is under review. These plans contain criteria for operating the Arrow, Duncan, Mica and Libby reservoirs.

**LIBBY DAM** Kootenai River, Montana

The dam and reservoir, Lake Koocanusa. The powerhouse is at the left of the spillway.

In April 1984 the Entities reached a long term storage agreement relating to the initial filling of non-Treaty reservoirs, the use of non-Treaty storage and Mica and Arrow reservoirs refill enhancement. In July 1990 the Entities signed a new non-Treaty Storage Agreement which extends the previous agreement by ten years, expands the amount of coordinated non-Treaty storage to be operated under the agreement and shares the responsibility to fill any new Columbia River reservoir built in British Columbia. This expanded storage agreement is expected to greatly benefit both Entities. The agreement went into effect early in this report year and is currently under review.

The Northwest Power Planning Council was established by Act of Congress in 1980 to prepare a program for improvement of fish and wildlife in the Columbia River basin and to develop a conservation and electric power plan for the Pacific Northwest. The Council, on 15 November 1982, adopted the Columbia River Basin Fish and Wildlife Program which establishes a water budget. This budget reserves 3.45 million acre-feet of storage upstream from Priest Rapids Dam on the Columbia River and 1.19 million acre-feet upstream from Lower Granite Dam on the Snake River. This storage is used by United States' project operators when it is required to improve low flows in the main rivers during the downstream migration of anadromous fish. Fisheries and native Indian interests control use of the storage for this purpose. The use of Canadian Treaty storage is advocated by the United States Northwest Power Planning Council in its Fish and Wildlife Program.

With regard to the use of Canadian Treaty storage to meet water budget purposes, the Board has stated in previous reports that the assured operating plans are to provide for optimum operation for power and flood control. The Board has also noted, however, that the Entities may agree to provide water for fish migration under detailed operating arrangements providing this does not conflict with Treaty requirements.

The Treaty specifies both the method for calculating dependable hydroelectric capacity to be credited to Canadian storage and a means for determining a limit which the capacity credit must not exceed. The Entities agree on the method for calculating the capacity credit, the benefits which accrue to Canadian Treaty Storage for meeting peak loads in the system. The appropriate approach for calculating limitations to the capacity credit is being evaluated by the Entities.

During the report year each Entity provided the Board with a paper setting out the Entity position on the calculation of limitations to the capacity credit. The Board received a technical briefing from each Entity on 25 April at which each Entity reviewed its position with regard to these calculations. The Entities are continuing their evaluations. The Board notes the importance of this matter and looks forward to its timely resolution within the coming year.

## Flood Control Operating Plans

The Treaty provides that Canadian storage reservoirs will be operated by the Canadian Entity in accordance with operating plans designed to minimize flood damage in the United States and Canada.

The Columbia River Treaty Flood Control Operating Plan defines flood control operation of the Duncan, Arrow, Mica and Libby reservoirs. This plan was received from the Entities and reviewed by the Board in the 1972-73 report year and is still in effect.

## Flow Records

Article XV(2)(a) of the Treaty specifies that the Permanent Engineering Board shall assemble records of flows of the Columbia and Kootenay Rivers at the Canada-United States of America boundary. Flows for this report year are tabulated in Appendix C for the Kootenai River at Porthill, Idaho and for the Columbia River at Birchbank, British Columbia.

## OPERATION

### General

The Columbia River Treaty Operating Committee was established by the Entities to develop operating plans for the Treaty storages and to direct operation of these storages in accordance with the terms of the Entity agreement.

During the report year the Treaty storage in Canada was operated by the Canadian Entity in accordance with:

— Columbia River Treaty Flood Control Operating Plan

— Detailed Operating Plan for Columbia River Treaty Storage 1 August 1990 through 31 July 1991

— Columbia River Treaty Hydroelectric Operating Plan, Assured Operating Plan for Operating Year 1990-91

— Columbia River Treaty Hydrolectric Operating Plan, Assured Operating Plan for Operating Year 1991-92

In addition, the following agreements were in effect during this period:

— An agreement between the Entities dated 9 April 1984 relating to:

  — Agreement between British Columbia Hydro and Power Authority and Bonneville Power Administration Relating to: (1) Initial Filling of non-Treaty Reservoirs, (2) The Use of Columbia River non-Treaty Storage and (3) Mica and Arrow Reservoir Refill Enhancement

  — Contract between Bonneville Power Administration and Mid-Columbia Purchasers Relating to Federal and Canadian Columbia River Storage

— Agreement executed by the United States of America Department of Energy acting by and through the Bonneville Power Administration and British Columbia Hydro and Power Authority relating to: (1) Use of Columbia River non-Treaty Storage, (2) Mica and Arrow Refill Enhancement and (3) Initial Filling of non-Treaty Reservoirs, signed 9 July 1990

— Columbia River Treaty Entity Agreement on Principles for the Preparation of the Assured Operating Plan and Determination of Downstream Power Benefits, July 1988

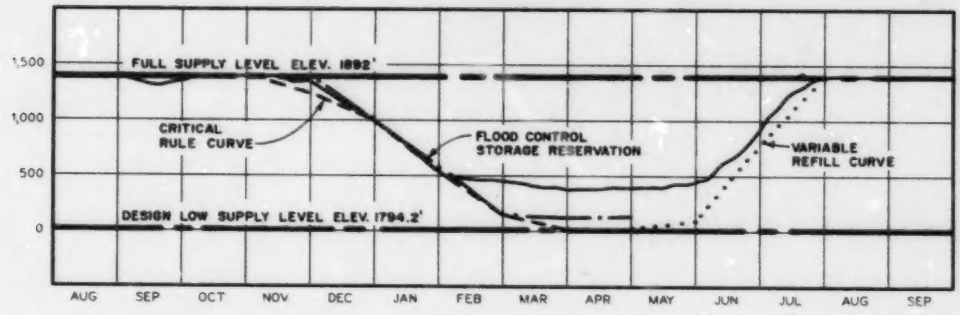
— Columbia River Treaty Entity Agreement on Changes to Procedures for the Preparation of the Assured Operating Plan and Determination of Downstream Power Benefit Studies, August 1988

Power Operation

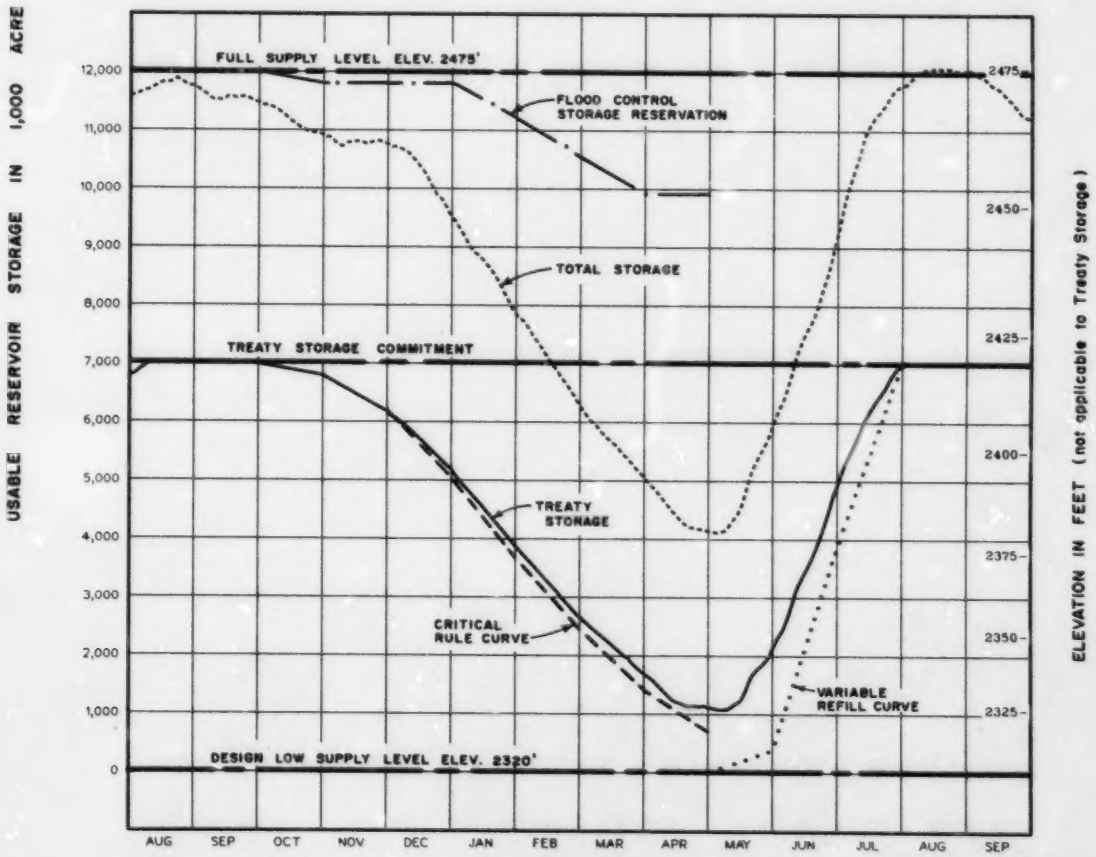
The three Canadian Treaty reservoirs, Duncan, Arrow and Mica, and the Libby reservoir in the United States were in full operation throughout this report year.

All Treaty storage filled during the summer of 1990. The coordinated system was operated at the start of the year in accordance with the first year critical rule curves. However, in September storages fell below rule curves and proportional drafting of the coordinated system was in effect for a short period. Heavy precipitation in November returned the reservoirs to rule curve levels and proportional drafting was not required after November.

Very dry weather over the basin in early October was followed by two heavy storms in November. Precipitation was generally above normal in the Canadian portion of the basin and near normal over the total Columbia River basin. The spring was cool, resulting in a protracted runoff. As a result, in spite of the unusually high snowpack in the Canadian portion of the basin, April through June natural flows at The Dalles would have been slightly below average and July and August flows well above average.

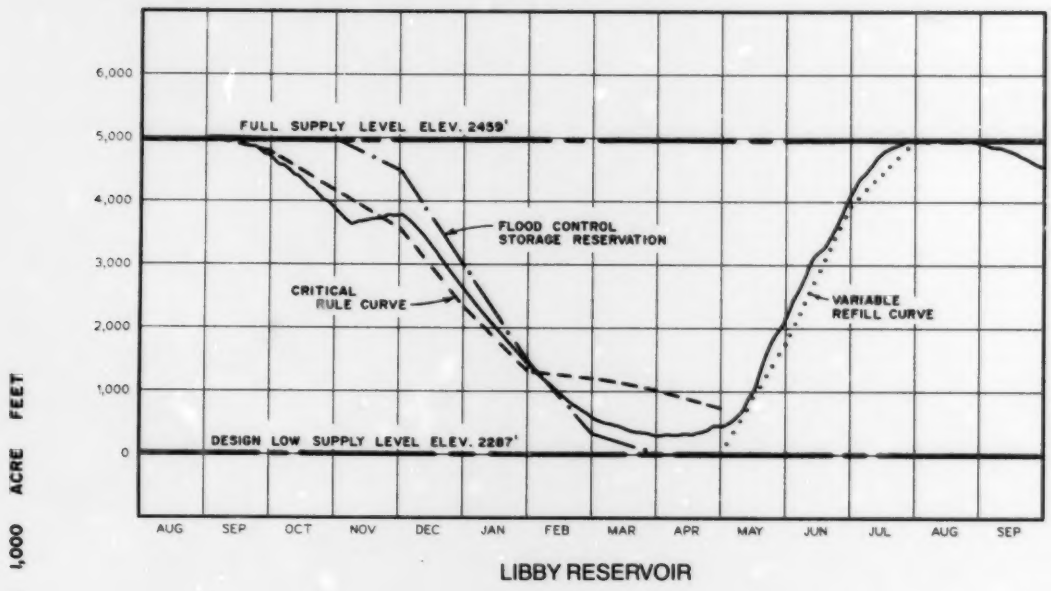



DUNCAN RESERVOIR

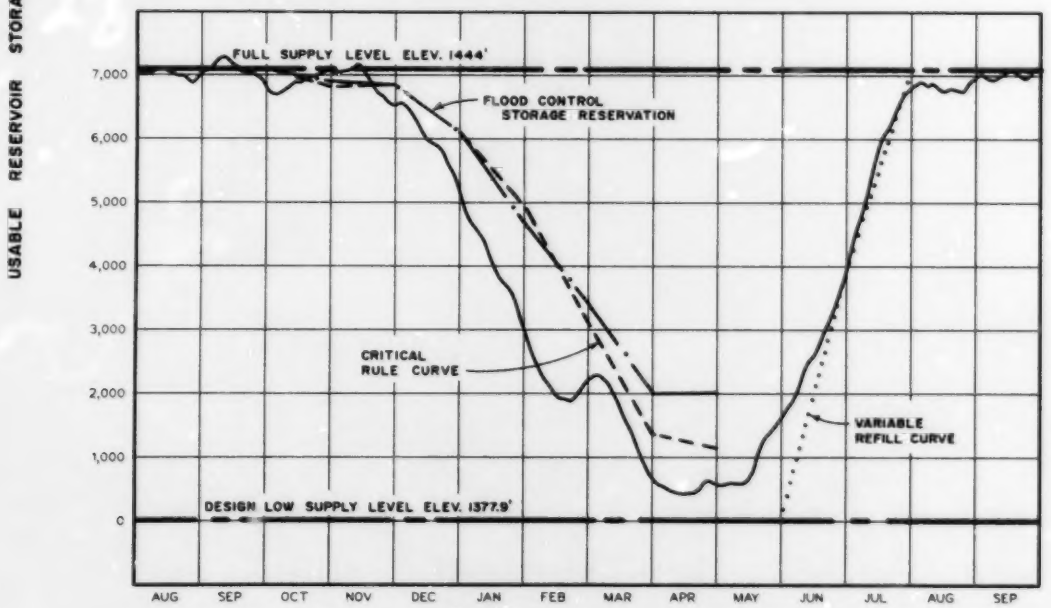



MICA RESERVOIR

HYDROGRAPHS — Duncan and Mica reservoir levels for the 14-month period ending 30 September 1991.




LIBBY RESERVOIR




ARROW RESERVOIR

HYDROGRAPHS — Libby and Arrow reservoir levels for the 14-month period ending 30 September 1991.

During the year some storage was transferred between the Treaty reservoirs. These storage transfers were accomplished without disrupting Treaty operations.

Commencing in the 1984 report year, operation in the United States incorporated requirements of the Northwest Power Planning Council's Fish and Wildlife Program. This program specifies a water budget for use during the period 15 April to 15 June to meet minimum flow requirements for the downstream migration of anadromous fish. In this report year, mid-Columbia streamflows were high enough throughout the entire spring water budget period that no mid-Columbia water budget releases were necessary.

Operation of the reservoirs is illustrated on pages 28 and 29 by hydrographs which show actual reservoir levels and some of the more important rule curves which govern operation of the Treaty storages. The Flood Control Storage Reservation curve specifies maximum month-end reservoir levels which will permit evacuation of the reservoir to control the forecast freshet. The Critical Rule Curve shows minimum month-end reservoir levels which should be maintained to enable the anticipated power demands to be met under the adverse water supply conditions. The Variable Refill Curve shows reservoir elevations necessary to ensure refilling the reservoir by the end of July with a reasonable degree of confidence. Similar rule curves which apply to operation of the combined Canadian Treaty storages have also been provided to the Board.

Mica reservoir was 4.8 feet below its full pool elevation of 2475 feet at the start of the report year, after having filled to within one foot of full pool in August 1990. Drafting of Treaty storage began on 1 October and proceeded slowly until 12 November. Then high inflows held the reservoir level steady at 2463 feet until 3 December. Drafting of both Treaty storage and non-Treaty storage then continued at a normal rate throughout the winter. The lowest level for the year was reached on 6 May, 2389.3 feet, 69.3 feet above minimum pool elevation.

Refill of Treaty storage was complete by 3 August, however, filling of non-Treaty storage continued. Full pool elevation of 2475 feet was reached on 8 August and spilling began. The reservoir surcharged to 2475.8 feet on 10 August. Treaty storage in the reservoir remained full throughout August and September while some non-Treaty storage was released. The reservoir ended the report year at elevation 2467.9 feet, about seven feet below full supply level.

At the beginning of the report year Arrow reservoir had been drafted to 1442.5 feet, 1.5 feet below full supply level of 1444 feet. The reservoir refilled in October, then began drafting again by mid-November. Drafting continued throughout the winter, except for the period 23 February to 7 March when the reservoir refilled by four feet. Between 23 March and mid-April, outlets were on free flow, releasing maximum possible discharge. On 17 April the reservoir reached its lowest level for 1991, 1381.5 feet, 3.6 feet above minimum pool elevation.

Treaty storage refilled until 3 August when the reservoir reached 1441.9 feet elevation. This was 2.1 feet below supply level, but with the surcharge held in Mica reservoir, Treaty storage in Arrow reservoir was considered full. The reservoir kept refilling and reached its maximum elevation for the year, 1444.1 feet, on 30 September.

Duncan reservoir began the report year at elevation 1889.1 feet, 2.9 feet below full pool elevation, after having been filled in August. The reservoir slowly refilled early in October and stayed full until mid-November. Drafting began 17 November and continued at a constant rate until 31 January. Discharge was reduced during February and March to help keep Kootenay Lake below its required level, and as a result the drafting of Duncan reservoir slowed. The reservoir reached its lowest level for the year at 1827.3 feet on 3 April, about 33 feet above its design minimum level.

Through April and May the reservoir was held low, and refilling did not begin until 25 May. The reservoir rapidly filled, reaching full supply elevation by 1 August. In mid-August, heavy rainfall in the area briefly surcharged the reservoir 0.7 feet above full supply elevation. Duncan reservoir remained full until the end of the report year.

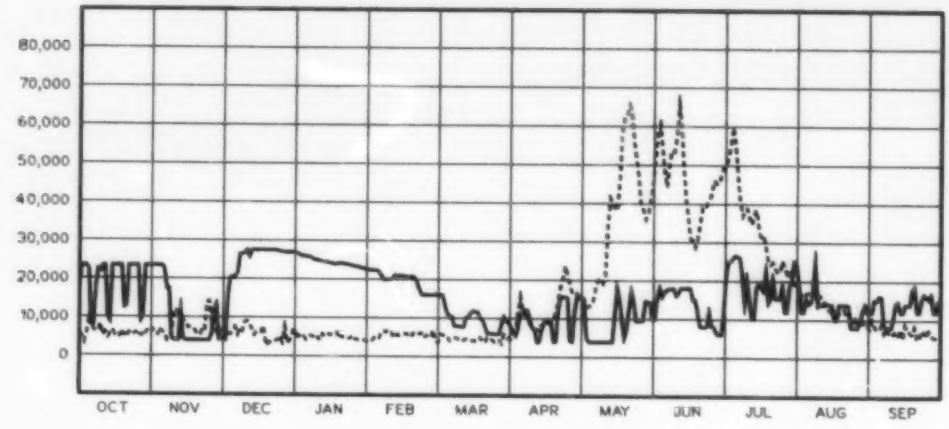
Libby reservoir had been drafted to 2453.6 feet at the start of the report year, 5.4 feet below its full supply elevation of 2459 feet. Drafting continued through October, then in early November the reservoir refilled a few feet when minimum flows were released following a series of fall storms. Drafting continued throughout the winter until the reservoir reached its lowest level for the year on 2 April at 2305.2 feet, 18.2 feet above the minimum pool elevation of 2287 feet.

Inflows were passed through the reservoir throughout April, then in early May outflow was reduced to begin rapid refilling. The reservoir reached its full supply elevation on 27 July, remained full throughout August, and drafting began in September. Libby reservoir was at elevation 2449.6 feet at the end of the report year.

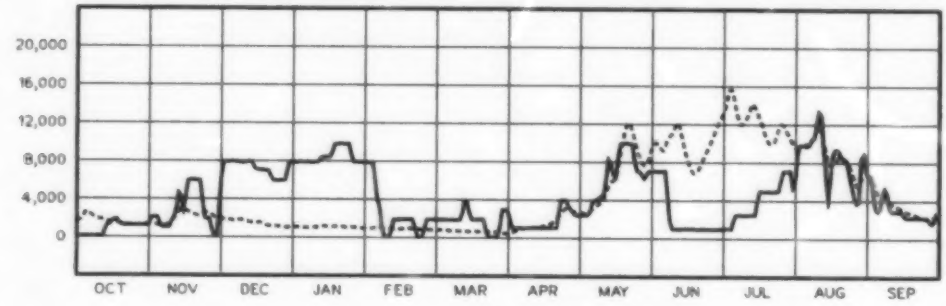
## Flood Control Operation

During the 1991 freshet, flood control was provided by normal refill of Treaty projects and other storage reservoirs in the Columbia River basin. Daily operation of reservoirs for flood control was in effect from 17 May to 18 June. The freshet was controlled to well below damaging level.

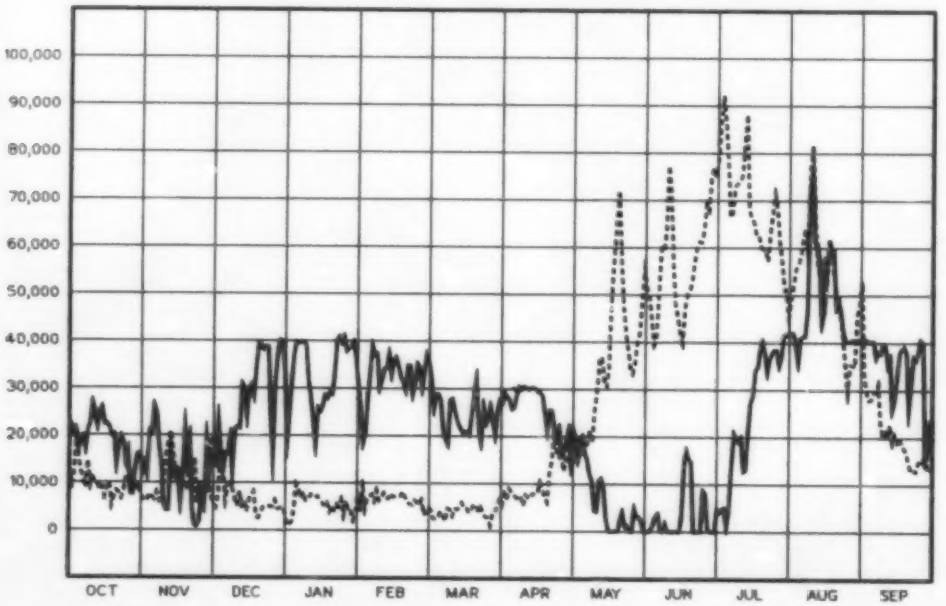
DISCHARGE IN CUBIC FEET PER SECOND



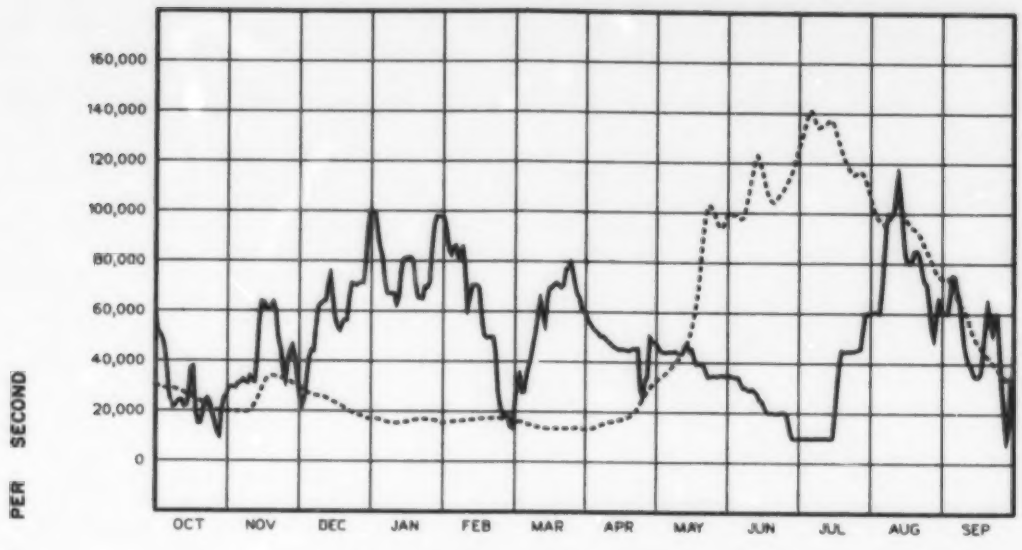

KOOTENAI RIVER AT LIBBY DAM



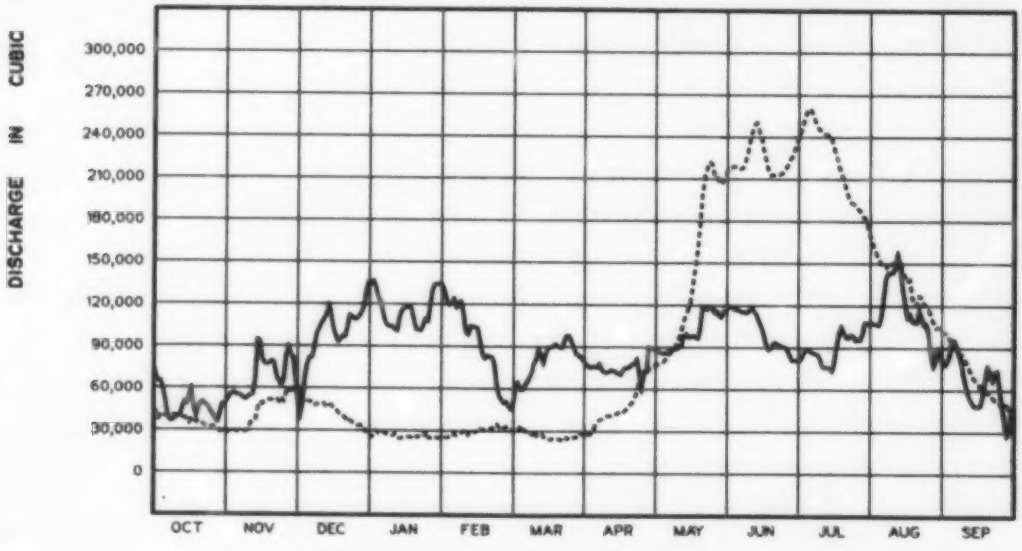

DUNCAN RIVER AT DUNCAN DAM




COLUMBIA RIVER AT MICA DAM




COLUMBIA RIVER AT HUGH KEENLEYSIDE DAM




COLUMBIA RIVER AT BIRCHBANK

**LEGEND**

——— Observed Flows

- - - - - Pre-Project Flows

HYDROGRAPHS — Observed and pre-project flows for year ending 30 September 1991.

## BENEFITS

### Flood Control Provided

Without regulation by upstream reservoirs, the 1991 freshet would have produced average freshet levels at Trail, British Columbia and at The Dalles, Oregon and would have caused significant flood damage in the United States.

It is estimated that the Duncan and Libby projects reduced the peak stage on Kootenay Lake by about five feet and that the Duncan, Arrow, Mica and Libby projects reduced the peak stage of the Columbia River at Trail, British Columbia by about nine and one-half feet. The effect of storage in the Duncan, Arrow, Mica and Libby reservoirs on flows at the sites and on flows of the Columbia River at Birchbank is illustrated on page 33 by hydrographs which show both the actual discharges and the flows that would have occurred if the dams had not been built. It is noted that the hydrograph showing preproject conditions for Birchbank has been computed on the assumption that the effects of Duncan, Arrow, Mica and Libby regulation and of the regulation provided by the Corra Linn development on Kootenay Lake have been removed.

The operation of Columbia Basin reservoirs for the system as a whole reduced the natural annual peak discharge of the Columbia River near The Dalles, Oregon from about 568,000 cfs to 348,000 cfs.

All payments required by Article VI(1) as compensation for flood control provided by the Canadian Treaty storage have been made by the United States to Canada; the final payment was made on 29 March 1973 when the Mica project was declared operational.

## Power Benefits

Downstream power benefits in the United States which arise from operation of the Canadian Treaty storage were pre-determined for the first thirty years of operation of each project and the Canadian one-half share was sold in the United States under the terms of the Canadian Entitlement Purchase Agreement. The United States Entity delivers capacity and energy to Columbia Storage Power Exchange participants as purchasers of the Canadian Entitlement. The benefits of additional generation made possible on the Kootenay River in Canada as a result of regulation provided by Libby, and generation at the Mica and Revelstoke projects, are retained wholly within Canada. The benefits from Libby regulation which occur downstream in the United States are not shareable under the Treaty.

The Canadian Entitlement Purchase Agreement terminates in stages beginning in 1998. Accordingly, downstream benefits are returnable to Canada as of the following dates:

| | |
|---|---|
| Duncan storage | 1 April 1998 |
| Arrow storage | 1 April 1999 |
| Mica storage | 1 April 2003 |

After 1 April 2003, Canada's share of downstream benefits is fully returnable.

## Other Benefits

By agreement between the Entities, streamflows are regulated for non-power purposes such as accommodating construction in river channels and providing water to assist the downstream migration of juvenile fish in the United States. These arrangements are implemented under the Detailed Operating Plan and provide mutual benefits.

## CONCLUSIONS

1. The Duncan, Arrow, Mica and Libby projects have been operated in conformity with the Treaty. Operation reflected detailed operating plans developed by the Entities, the flood control operating plan for Treaty reservoirs, and the 1984 non-Treaty storage agreement between the Entities relating to the use of non-Treaty storage, refill enhancement of Mica and Arrow reservoirs, and initial filling of non-Treaty reservoirs. Operation under this agreement did not conflict with normal Treaty operations.

2. The Entities have reached agreement on the Detailed Operating Plan for Columbia River Treaty Storage for 1991-92.

3. Entity evaluations pertaining to development of the hydrometeorological network, power operating plans, and the calculation of downstream power benefits are proceeding. The Assured Operating Plan and the Determination of Downstream Power Benefits and Options for Development of the Detailed Operating Plan for Operating Years 1996-97 was not received. The Board expressed interest to the Entities in being able to review this document at an early date.

4. The Assured Operating Plan and downstream benefit document for 1997-98, due for completion in October 1992, will be the first to contain benefits not covered by the Sales Agreement.

5. The Entities are continuing to develop plans for the return of the Canadian Entitlement commencing in operating year 1997-98.

6. The Entities have not yet reached a common understanding as to how the limitations for capacity credits should be determined. The Entities are continuing their evaluations. The Board notes the importance of this matter and looks forward to its timely resolution within the coming year.

7. The objectives of the Treaty are being met.

APPENDIX A

## COLUMBIA RIVER TREATY PERMANENT ENGINEERING BOARD

### Members

**United States**

Mr. Herbert Kennon, Chairman
Deputy Director
Directorate of Civil Works
H.Q., U.S. Army Corps of Engineers
Washington, DC

Mr. Ronald Wilkerson
4655 Highway 200 East
Missoula, Montana

**Canada**

Mr. David Oulton, Chairman 1)
Assistant Deputy Minister
Energy Sector
Energy, Mines and Resources Canada
Ottawa, Ontario

Mr. John Allan 2)
Deputy Minister
Ministry of Energy, Mines and
Petroleum Resources
Victoria, BC

### Alternates

Mr. John Elmore
Chief, Operations, Construction and
Readiness Division
Directorate of Civil Works
H.Q., U.S. Army Corps of Engineers,
Washington, DC

Mr. Thomas Weaver
Assistant Administrator for Engineering
Western Area Power Administration
Department of Energy
Golden, Colorado

Mr. Mac Clark
4376 Starlight Way
North Vancouver, BC

Dr. Donald Kasianchuk
Comptroller of Water Rights
Ministry of Environment
Victoria, BC

### Secretaries

Mr. Shapur Zanganeh
Hydraulics and Hydrology Branch
Directorate of Civil Works
H.Q., U.S. Army Corps of Engineers
Washington, DC

Mr. Mac Clark
4376 Starlight Way
North Vancouver, BC

1) Vice Mr. Gordon MacNabb as of 19 November 1991.
2) Vice Mr. Douglas Horswill as of 30 April 1991.

APPENDIX A

## COLUMBIA RIVER TREATY PERMANENT ENGINEERING BOARD

### Record of Membership

| United States | | Canada | |
|---|---|---|---|
| **Members** | | | |
| Mr. Wendell Johnson 1) | 1964-1970 | Mr. Gordon MacNabb 1) | 1964-1991 |
| Mr. Morgan Dubrow | 1964-1970 | Mr. Arthur Paget | 1964-1973 |
| Mr. John Neuberger | 1970-1973 | Mr. Valter Raudsepp | 1973-1974 |
| Mr. Joseph Caldwell 1) | 1971-1973 | Mr. Ben Marr | 1974-1987 |
| Mr. Homer Willis 1) | 1973-1979 | Mr. Tom Johnson | 1987-1988 |
| Mr. King Mallory | 1973-1975 | Mr. Douglas Horswill | 1989-1991 |
| Mr. Raymond Peck, Jr. | 1976-1977 | Mr. John Allan 2) | 1991- |
| Mr. Emerson Harper | 1978-1988 | Mr. David Oulton 1) 3) | 1991- |
| Mr. Lloyd Duscha 1) | 1979-1990 | | |
| Mr. Ronald Wilkerson | 1988- | | |
| Mr. Herbert Kennon 1) | 1990- | | |
| **Alternates** | | | |
| Mr. Fred Thrall | 1964-1974 | Mr. Mac Clark | 1964- |
| Mr. Emerson Harper | 1964-1978 | Mr. Jim Rothwell | 1964-1965 |
| Mr. Alex Shwaiko | 1974-1987 | Mr. Hugh Hunt | 1966-1988 |
| Mr. Thomas Weaver | 1979- | Dr. Donald Kasianchuk | 1988- |
| Mr. Herbert Kennon | 1987-1990 | | |
| Mr. John Elmore | 1990- | | |
| **Secretaries** | | | |
| Mr. John Roche | 1965-1969 | Mr. Mac Clark | 1964- |
| Mr. Verle Farrow | 1969-1972 | | |
| Mr. Walter Duncan | 1972-1978 | | |
| Mr. Shapur Zanganeh | 1978- | | |

1) Chairman.
2) Vice Mr. Douglas Horswill as of 30 April 1991.
3) Vice Mr. Gordon MacNabb as of 19 November 1991.

APPENDIX A

## COLUMBIA RIVER TREATY PERMANENT ENGINEERING BOARD

## ENGINEERING COMMITTEE

### Current Membership

| United States | Canada |
|---|---|
| **Members** | |
| Mr. Shapur Zanganeh, Chairman<br>Hydraulics and Hydrology Branch<br>Directorate of Civil Works<br>H.Q., U.S. Army Corps of Engineers<br>Washington, DC | Mr. Neill Lyons, Chairman<br>Inland Waters Directorate<br>Environment Canada<br>North Vancouver, BC |
| Mr. Gary Fuqua<br>Office of Energy Resources<br>Bonneville Power Administration<br>Portland, Oregon | Mr. Dave McCauley<br>Electricity Branch<br>Energy, Mines and Resources Canada<br>Ottawa, Ontario |
| Mr. Larry Eilts<br>Western Area Power Administration<br>Department of Energy<br>Golden, Colorado | Mr. Roger McLaughlin<br>Energy Resources Division<br>Ministry of Energy, Mines and Petroleum Resources<br>Victoria, BC |
| Mr. Earl Eiker<br>Hydraulics and Hydrology Branch<br>Directorate of Civil Works<br>H.Q., U.S. Army Corps of Engineers<br>Washington, DC | Mr. Robin Round<br>Water Management Division<br>Ministry of Environment<br>Victoria, BC |
| **Alternates** | |
| Mr. Richard Mittelstadt<br>Water Management Division<br>U.S. Army Corps of Engineers<br>North Pacific Division<br>Portland, Oregon | |
| Mr. Steve Wright<br>Bonneville Power Administration<br>Department of Energy<br>Washington, DC | |

APPENDIX B

## COLUMBIA RIVER TREATY ENTITIES

| United States | Canada |
|---|---|
| **Members** | |
| Mr. Randall Hardy, Acting Chairman 1)<br>Administrator, Bonneville<br>Power Administration<br>Department of Energy<br>Portland, Oregon | Mr. Robert Wyman, Chairman 2)<br>Chairman, British Columbia Hydro<br>and Power Authority<br>Vancouver, BC |
| Major General Ernest Harrell 3)<br>Division Engineer<br>U.S. Army Engineer Division, North Pacific<br>Portland, Oregon | |

1) Vice Mr. Jack Robertson as of 22 November 1991, who succeeded Mr. James Jura as of 16 August 1991.
2) Vice Mr. Larry Bell as of 1 March 1991.
3) Vice Brigadier General Pat M. Stevens IV as of 2 March 1991.

APPENDIX C

# RECORD OF FLOWS

# AT THE

# INTERNATIONAL BOUNDARY

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6,940 | 27,600 | 12,100 | 30,400 | 25,200 | 20,300 | 12,600 | 27,200 | 34,100 | 15,100 | 27,000 | 12,400 |
| 2 | 19,100 | 27,100 | 10,500 | 30,000 | 25,400 | 19,900 | 13,200 | 27,600 | 30,600 | 19,700 | 25,100 | 12,300 |
| 3 | 24,300 | 26,500 | 10,200 | 29,500 | 25,200 | 20,100 | 13,300 | 27,200 | 31,500 | 30,500 | 20,000 | 12,700 |
| 4 | 24,900 | 26,300 | 21,100 | 28,800 | 25,800 | 21,100 | 13,000 | 24,200 | 37,000 | 33,800 | 14,200 | 15,400 |
| 5 | 25,300 | 26,000 | 25,300 | 28,700 | 27,100 | 21,600 | 23,100 | 16,600 | 37,100 | 34,000 | 13,600 | 16,200 |
| 6 | 22,200 | 26,000 | 25,500 | 28,500 | 28,900 | 19,500 | 40,500 | 15,400 | 32,200 | 34,800 | 16,800 | 16,400 |
| 7 | 11,000 | 22,200 | 25,200 | 28,300 | 27,400 | 16,500 | 37,700 | 16,800 | 33,700 | 34,400 | 15,400 | 15,400 |
| 8 | 9,750 | 19,800 | 28,700 | 28,200 | 25,800 | 15,900 | 29,700 | 19,100 | 35,700 | 33,400 | 15,800 | 9,610 |
| 9 | 20,600 | 18,500 | 31,300 | 27,800 | 25,200 | 15,100 | 26,400 | 22,000 | 35,600 | 32,100 | 19,800 | 8,860 |
| 10 | 23,200 | 12,000 | 32,300 | 27,500 | 25,000 | 12,500 | 24,300 | 21,300 | 35,000 | 24,400 | 23,000 | 8,810 |
| 11 | 24,400 | 14,400 | 34,000 | 27,600 | 24,800 | 12,200 | 21,000 | 20,400 | 37,500 | 19,400 | 15,400 | 8,780 |
| 12 | 25,600 | 11,600 | 33,300 | 27,700 | 25,700 | 11,900 | 17,500 | 21,400 | 38,600 | 24,000 | 15,000 | 11,500 |
| 13 | 24,100 | 10,400 | 33,400 | 28,500 | 25,900 | 11,800 | 16,000 | 26,400 | 36,400 | 18,800 | 15,000 | 14,000 |
| 14 | 12,000 | 15,700 | 33,800 | 28,800 | 25,800 | 11,500 | 13,400 | 28,400 | 34,100 | 14,600 | 15,700 | 14,500 |
| 15 | 13,300 | 9,690 | 33,300 | 28,700 | 25,900 | 13,000 | 13,500 | 27,400 | 31,900 | 14,100 | 15,100 | 12,800 |
| 16 | 24,100 | 8,410 | 33,000 | 28,500 | 25,800 | 13,700 | 15,800 | 26,600 | 30,500 | 21,100 | 15,000 | 12,800 |
| 17 | 25,500 | 7,820 | 33,000 | 28,200 | 26,100 | 14,400 | 17,700 | 34,500 | 29,600 | 22,100 | 14,200 | 14,000 |
| 18 | 25,400 | 7,590 | 33,200 | 27,700 | 26,300 | 14,800 | 18,200 | 47,900 | 27,700 | 21,600 | 11,300 | 14,100 |
| 19 | 25,500 | 7,440 | 32,400 | 28,200 | 26,200 | 14,900 | 18,500 | 53,700 | 24,700 | 22,500 | 11,800 | 14,400 |
| 20 | 23,700 | 7,160 | 31,400 | 28,000 | 27,100 | 14,500 | 19,100 | 45,800 | 25,100 | 24,800 | 14,400 | 18,000 |
| 21 | 15,100 | 7,050 | 30,900 | 27,700 | 28,400 | 13,300 | 16,100 | 38,300 | 25,400 | 16,800 | 14,600 | 17,900 |
| 22 | 16,300 | 6,890 | 30,700 | 27,400 | 26,800 | 12,900 | 17,700 | 38,600 | 20,900 | 17,700 | 14,600 | 12,900 |
| 23 | 24,800 | 7,600 | 30,700 | 27,100 | 24,100 | 12,000 | 28,600 | 43,000 | 18,700 | 21,000 | 14,700 | 12,600 |
| 24 | 25,600 | 10,900 | 30,900 | 26,900 | 22,300 | 10,200 | 35,100 | 46,800 | 17,800 | 17,800 | 13,600 | 16,000 |
| 25 | 25,500 | 33,500 | 31,000 | 26,700 | 21,700 | 9,880 | 37,600 | 37,300 | 17,800 | 17,500 | 9,650 | 16,400 |
| 26 | 25,600 | 36,200 | 30,900 | 26,200 | 21,300 | 10,200 | 35,200 | 30,900 | 21,000 | 17,900 | 9,380 | 16,000 |
| 27 | 23,400 | 25,600 | 30,700 | 26,100 | 20,900 | 9,600 | 29,300 | 28,100 | 17,500 | 20,500 | 9,310 | 15,500 |
| 28 | 12,400 | 24,300 | 30,900 | 25,900 | 20,400 | 9,460 | 19,100 | 26,700 | 17,000 | 14,800 | 9,660 | 16,200 |
| 29 | 13,600 | 23,900 | 30,300 | 25,400 | | 9,500 | 17,100 | 27,500 | 16,000 | 14,000 | 10,800 | 12,600 |
| 30 | 24,400 | 14,300 | 30,000 | 25,000 | | 11,400 | 24,600 | 33,000 | 15,400 | 19,500 | 13,100 | 12,500 |
| 31 | 26,300 | | 30,100 | 25,000 | | 12,000 | | 34,000 | | 24,300 | 14,200 | |
| Mean | 20,770 | 17,420 | 28,710 | 27,710 | 25,230 | 14,050 | 22,160 | 30,130 | 28,200 | 22,480 | 15,080 | 13,720 |

KOOTENAI RIVER AT PORTHILL, IDAHO — Daily discharges for the year ending 30 September 1991 in cubic feet per second.

| Day | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 75,900 | 51,200 | 52,600 | 135,000 | 130,000 | 45,600 | 80,800 | 89,200 | 117,000 | 80,900 | 108,000 | 77,300 |
| 2 | 67,500 | 54,400 | 41,000 | 137,000 | 122,000 | 49,800 | 78,500 | 88,300 | 119,000 | 80,500 | 108,000 | 77,900 |
| 3 | 65,000 | 56,500 | 49,800 | 132,000 | 119,000 | 60,000 | 76,500 | 87,700 | 119,000 | 82,400 | 107,000 | 80,800 |
| 4 | 65,000 | 57,200 | 68,200 | 124,000 | 121,000 | 64,300 | 75,300 | 86,200 | 119,000 | 85,800 | 107,000 | 85,900 |
| 5 | 59,000 | 55,400 | 77,700 | 121,000 | 124,000 | 59,500 | 76,000 | 85,700 | 117,000 | 88,700 | 106,000 | 95,600 |
| 6 | 51,900 | 55,400 | 81,900 | 113,000 | 118,000 | 59,300 | 76,200 | 86,200 | 117,000 | 88,500 | 113,000 | 95,600 |
| 7 | 40,600 | 54,700 | 81,900 | 106,000 | 121,000 | 61,900 | 75,600 | 85,300 | 117,000 | 87,200 | 127,000 | 89,500 |
| 8 | 36,400 | 52,600 | 89,300 | 104,000 | 122,000 | 64,900 | 78,100 | 88,100 | 115,000 | 86,400 | 140,000 | 84,700 |
| 9 | 36,700 | 51,900 | 99,200 | 104,000 | 114,000 | 68,300 | 73,700 | 89,100 | 115,000 | 85,900 | 144,000 | 78,500 |
| 10 | 38,100 | 53,700 | 103,000 | 104,000 | 100,000 | 72,100 | 72,500 | 88,600 | 115,000 | 85,400 | 143,000 | 68,200 |
| 11 | 39,600 | 55,100 | 107,000 | 102,000 | 98,500 | 78,400 | 71,500 | 88,900 | 117,000 | 81,800 | 144,000 | 62,600 |
| 12 | 39,900 | 55,400 | 109,000 | 101,000 | 105,000 | 81,300 | 72,500 | 90,800 | 118,000 | 76,800 | 148,000 | 55,400 |
| 13 | 44,800 | 65,700 | 113,000 | 111,000 | 105,000 | 88,000 | 73,900 | 92,500 | 116,000 | 75,800 | 156,000 | 52,200 |
| 14 | 50,100 | 94,800 | 119,000 | 116,000 | 104,000 | 84,400 | 73,300 | 98,400 | 114,000 | 76,300 | 148,000 | 49,200 |
| 15 | 48,700 | 93,600 | 113,000 | 118,000 | 103,000 | 78,600 | 72,700 | 99,900 | 108,000 | 75,900 | 132,000 | 48,300 |
| 16 | 53,300 | 79,800 | 102,000 | 118,000 | 94,800 | 84,700 | 70,900 | 97,300 | 105,000 | 73,500 | 121,000 | 48,400 |
| 17 | 59,000 | 77,300 | 97,500 | 119,000 | 84,900 | 89,700 | 70,300 | 98,000 | 100,000 | 79,900 | 112,000 | 49,600 |
| 18 | 46,300 | 77,000 | 93,200 | 117,000 | 81,600 | 90,100 | 73,500 | 98,500 | 92,000 | 91,400 | 114,000 | 57,000 |
| 19 | 40,300 | 78,000 | 94,600 | 109,000 | 83,700 | 90,200 | 75,600 | 97,200 | 88,200 | 100,000 | 109,000 | 68,500 |
| 20 | 46,600 | 79,500 | 97,500 | 102,000 | 83,100 | 92,000 | 75,300 | 96,500 | 89,700 | 105,000 | 108,000 | 76,700 |
| 21 | 49,400 | 78,000 | 97,100 | 102,000 | 82,500 | 91,300 | 76,600 | 104,000 | 93,200 | 101,000 | 108,000 | 72,800 |
| 22 | 50,500 | 67,800 | 104,000 | 101,000 | 78,700 | 89,600 | 77,900 | 119,000 | 94,100 | 97,300 | 116,000 | 67,100 |
| 23 | 48,400 | 65,000 | 112,000 | 106,000 | 64,700 | 88,500 | 78,800 | 119,000 | 92,500 | 97,200 | 112,000 | 73,200 |
| 24 | 47,300 | 62,200 | 111,000 | 110,000 | 55,200 | 94,500 | 81,700 | 117,000 | 91,700 | 99,400 | 106,000 | 74,000 |
| 25 | 43,800 | 66,000 | 109,000 | 108,000 | 52,300 | 98,000 | 71,000 | 119,000 | 90,700 | 99,000 | 107,000 | 61,300 |
| 26 | 41,300 | 63,700 | 109,000 | 120,000 | 49,900 | 98,000 | 60,900 | 119,000 | 90,900 | 95,400 | 100,000 | 47,800 |
| 27 | 37,800 | 89,700 | 112,000 | 131,000 | 51,000 | 94,400 | 73,000 | 115,000 | 89,100 | 96,400 | 85,100 | 38,800 |
| 28 | 36,000 | 84,000 | 115,000 | 135,000 | 47,500 | 89,300 | 72,900 | 116,000 | 84,800 | 95,700 | 76,900 | 27,700 |
| 29 | 42,000 | 81,600 | 120,000 | 135,000 | | 84,700 | 90,500 | 113,000 | 80,800 | 100,000 | 82,000 | 30,700 |
| 30 | 48,700 | 68,500 | 130,000 | 135,000 | | 84,500 | 89,700 | 112,000 | 81,100 | 109,000 | 89,800 | 47,500 |
| 31 | 49,100 | | 136,000 | 134,000 | | 82,700 | | 116,000 | | 108,000 | 87,400 | |
| Mean | 48,400 | 68,200 | 98,200 | 116,000 | 93,400 | 79,300 | 75,500 | 100,000 | 104,000 | 89,900 | 115,000 | 64,800 |

COLUMBIA RIVER AT BIRCHBANK, B.C. — Daily discharges for the year ending 30 September 1991 in cubic feet per second.

## APPENDIX D

## PROJECT INFORMATION


Power and Storage Projects,
Northern Columbia Basin — Plate No. 1

Project Data
Duncan Project — Table No. 1
Arrow Project — Table No. 2
Mica Project — Table No. 3
Libby Project — Table No. 4

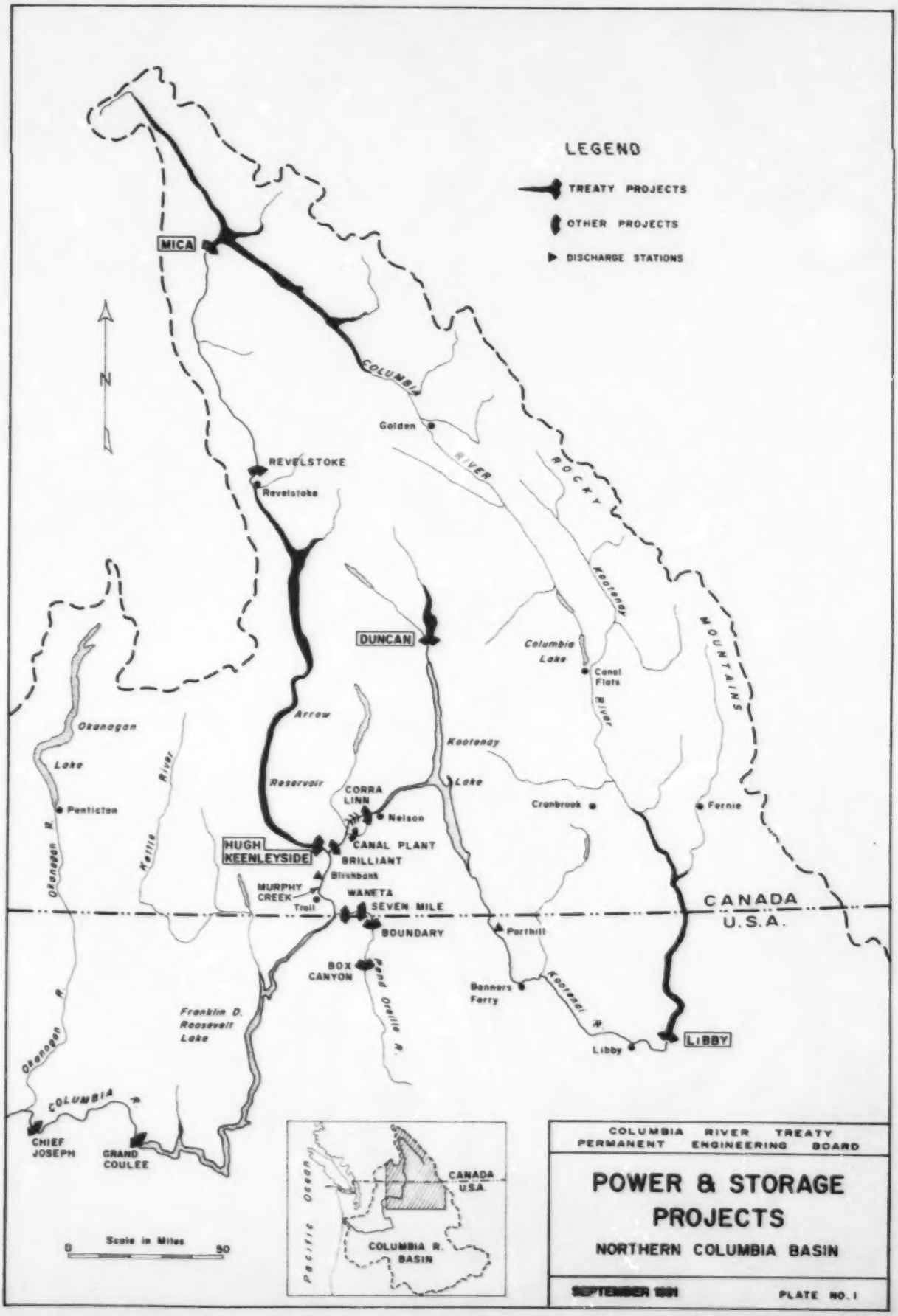

LEGEND
TREATY PROJECTS
OTHER PROJECTS
DISCHARGE STATIONS
N
MICA
COLUMBIA
Golden
REVELSTOKE
Revelstoke
ROCKY
RIVER
Kootenay
MOUNTAINS
DUNCAN
Columbia Lake
Canal Flats
River
Arrow
Reservoir
Okanagan
Lake
Penticton
Okanagon R.
Kettle River
CORRA LINN
Nelson
Kootenay
Lake
Cranbrook
Fernie
HUGH KEENLEYSIDE
CANAL PLANT
BRILLIANT
Birchbank
MURPHY CREEK
Trail
WANETA
SEVEN MILE
BOUNDARY
CANADA
U.S.A.
Porthill
BOX CANYON
Pend Oreille R.
Bonners Ferry
Kootenai R.
Libby
LIBBY
Franklin D. Roosevelt Lake
Okanogan R.
COLUMBIA
CHIEF JOSEPH
GRAND COULEE
Scale in Miles
0
30
Pacific Ocean
CANADA
U.S.A.
COLUMBIA R. BASIN
COLUMBIA RIVER TREATY
PERMANENT ENGINEERING BOARD
POWER & STORAGE PROJECTS
NORTHERN COLUMBIA BASIN
SEPTEMBER 1991
PLATE NO. 1

TABLE 1

## DUNCAN PROJECT

### Duncan Dam and Duncan Lake

| | |
|---|---|
| **Storage Project** | |
| Construction began | 17 September 1964 |
| Storage became fully operational | 31 July 1967 |
| **Reservoir** | |
| Normal Full Pool Elevation | 1,892 feet |
| Normal Minimum Pool Elevation | 1,794.2 feet |
| Surface Area at Full Pool | 18,000 acres |
| Total Storage Capacity | 1,432,400 ac-ft |
| Usable Storage Capacity | 1,400,000 ac-ft |
| Treaty Storage Commitment | 1,400,000 ac-ft |
| **Dam, Earthfill** | |
| Crest Elevation | 1,907 feet |
| Length | 2,600 feet |
| Approximate height above riverbed | 130 feet |
| Spillway — Maximum Capacity | 47,700 cfs |
| Discharge Tunnels — Maximum Capacity | 20,000 cfs |
| **Power Facilities** | |
| None | |

TABLE 2

## ARROW PROJECT

### Hugh Keenleyside Dam and Arrow Lakes

| | |
|---|---|
| **Storage Project** | |
| Construction began | March 1965 |
| Storage became fully operational | 10 October 1968 |
| **Reservoir** | |
| Normal Full Pool Elevation | 1,444 feet |
| Normal Minimum Pool Elevation | 1,377.9 feet |
| Surface Area at Full Pool | 130,000 acres |
| Total Storage Capacity | 8,337,000 ac-ft |
| Usable Storage Capacity | 7,100,000 ac-ft |
| Treaty Storage Commitment | 7,100,000 ac-ft |
| **Dam, Concrete Gravity and Earthfill** | |
| Crest Elevation | 1,459 feet |
| Length | 2,850 feet |
| Approximate height above riverbed | 170 feet |
| Spillway — Maximum Capacity | 240,000 cfs |
| Low Level Outlets — Maximum Capacity | 132,000 cfs |
| **Power Facilities** | |
| None | |

TABLE 3

## MICA PROJECT

### Mica Dam and Kinbasket Lake

| | |
|---|---|
| **Storage Project** | |
| Construction began | September 1965 |
| Storage became fully operational | 29 March 1963 |
| **Reservoir** | |
| Normal Full Pool Elevation | 2,475 feet |
| Normal Minimum Pool Elevation | 2,320 feet |
| Surface Area at Full Pool | 106,000 acres |
| Total Storage Capacity | 20,000,000 ac-ft |
| Usable Storage Capacity | |
| Total | 12,000,000 ac-ft |
| Commitment to Treaty | 7,000,000 ac-ft |
| **Dam, Earthfill** | |
| Crest Elevation | 2,500 feet |
| Length | 2,600 feet |
| Approximate height above foundation | 800 feet |
| Spillway — Maximum Capacity | 150,000 cfs |
| Outlet Works — Maximum Capacity | 37,400 cfs |
| **Power Facilities** | |
| Designed ultimate installation | |
| 6 units at 434 mw | 2,604 mw |
| Power commercially available | December 1976 |
| Presently installed | |
| 4 units at 434 mw | 1,736 mw |
| Head at full pool | 600 feet |
| Maximum Turbine Discharge | |
| of 4 units at full pool | 38,140 cfs |

TABLE 4

## LIBBY PROJECT

### Libby Dam and Lake Koocanusa

| | |
|---|---|
| **Storage Project** | |
| Construction began | June 1966 |
| Storage became fully operational | 17 April 1973 |
| **Reservoir** | |
| Normal Full Pool Elevation | 2,459 feet |
| Normal Minimum Pool Elevation | 2,287 feet |
| Surface Area at Full Pool | 46,500 acres |
| Total Storage Capacity | 5,869,000 ac-ft |
| Usable Storage Capacity | 4,980,000 ac-ft |
| **Dam, Concrete Gravity** | |
| Deck Elevation | 2,472 feet |
| Length | 3,055 feet |
| Approximate height above riverbed | 370 feet |
| Spillway — Maximum Capacity | 145,000 cfs |
| Low Level Outlets — Maximum Capacity | 61,000 cfs |
| **Power Facilities** | |
| Designed ultimate installation | |
| 8 units at 105 mw | 840 mw |
| Power commercially available | 24 August 1975 |
| Presently installed | |
| 5 units at 105 mw | 525 mw |
| Head at full pool | 352 feet |
| Maximum Turbine Discharge | |
| of 5 units at full pool | 26,500 cfs |